(27)

Evaluation of white-to-white distance and anterior chamber depth measurements using the IOL Master, slit-lamp adapted optical coherence tomography and digital photographs in phakic eyes

Ocena średnicy „white-to-white" i głębokości komory przedniej w oczach soczewkowych za pomocą soczewek wewnątrzgałkowych IOL Master, optycznej koherentnej tomografii przedniego odcinka i cyfrowych fotografii

Michał Wilczyński, Aleksandra Pośpiech-Żabierek

Department of Ophthalmology, 1st Chair of Ophthalmology, Medical University of Łódź
Head: Professor Wojciech Omulecki, PhD, MD

Abstract: Introduction: The accurate measurement of the anterior chamber internal diameter and depth is important in ophthalmic diagnosis and before some eye surgery procedures.
The purpose of the study was to compare the white-to-white distance measurements performed using the IOL-Master and photography with internal anterior chamber diameter determined using slit lamp adapted optical coherence tomography in healthy eyes, and to compare anterior chamber depth measurements by IOL-Master and slit lamp adapted optical coherence tomography.
Material and methods: The data were gathered prospectively from a non-randomized consecutive series of patients. The examined group consisted of 46 eyes of 39 patients. White-to-white was measured using IOL-Master and photographs of the eye were taken with a digital camera. Internal anterior chamber diameter was measured with slit-lamp adapted optical coherence tomography. Anterior chamber depth was measured using the IOL Master and slit-lamp adapted optical coherence tomography. Statistical analysis was performed using parametric tests. A Bland-Altman plot was drawn.
Results: White-to-white distance by the IOL Master was 11.8±0.40 mm, on photographs it was 11.29±0.58 mm and internal anterior chamber diameter by slit-lamp adapted optical coherence tomography was 11.34±0.54 mm. A significant difference was found between IOL-Master and slit-lamp adapted optical coherence tomography ($p<0.01$), as well as between IOL Master and digital photographs ($p<0.01$). There was no difference between SL-OCT and digital photographs ($p>0.05$). All measurements were correlated (Spearman $p<0.001$).
Mean anterior chamber depth determined using the IOL-Master was 2.99±0.50 mm and by slit-lamp adapted optical coherence tomography was 2.56±0.46 mm. The difference was statistically significant ($p<0.001$). The correlation between the values was also statistically significant (Spearman, $p<0.001$).
Conclusions: Automated measurements using IOL-Master yield constantly higher values than measurements based on direct eye visualization slit-lamp adapted optical coherence tomography and digital photographs.
In order to obtain accurate measurements of the internal anterior chamber diameter and anterior chamber depth, a method involving direct visualization of intraocular structures should be used.
Key words: white-to-white, slit-lamp adapted optical coherence tomography – SL-OCT, IOL-Master, digital photography, measurements.
Abstrakt: Wstęp: pomiary średnicy komory przedniej oraz jej głębokości są istotne jako element oceny przedoperacyjnej oraz w diagnostyce okulistycznej.
Cel: celem pracy jest ocena zgodności pomiarów odległości „white-to-white" uzyskanych za pomocą IOL Master, optycznej koherentnej tomografii przedniego odcinka oraz fotografii cyfrowych, a także ocena zgodności pomiarów średnicy komory przedniej uzyskanych za pomocą IOL Master i optycznej koherentnej tomografii przedniego odcinka.
Materiał i metody: badano prospektywnie nierandomizowaną grupę kolejnych pacjentów. Do grupy badanej włączono 46 oczu (39 pacjentów). Wymiar „white-to-white" mierzono za pomocą IOL Master, optycznej koherentnej tomografii przedniego odcinka oraz fotografii cyfrowych. Głębokość komory przedniej zmierzono za pomocą urządzenia IOL Master i optycznej koherentnej tomografii przedniego odcinka. Do analizy statystycznej użyto testów parametrycznych i statystyki Blanda-Altmana.
Wyniki: średnica „white-to-white" zmierzona przez IOL Master wynosiła 11,8±0,40 mm, na fotografiach cyfrowych wynosiła 11,29±0,58 mm, zmierzona zaś za pomocą optycznej koherentnej tomografii przedniego odcinka – 11,34±0,54 mm. Stwierdzono istotną różnicę między pomiarami uzyskanymi za pomocą IOL Master a pomiarami uzyskanymi za pomocą optycznej koherentnej tomografii przedniego odcinka ($p<0,01$), a także między pomiarami uzyskanymi za pomocą IOL Master i za pomocą fotografii cyfrowych ($p<0,01$).

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Nie stwierdzono różnicy między pomiarami wykonanymi za pomocą optycznej koherentnej tomografii przedniego odcinka i za pomocą fotografii cyfrowych (p>0,05). Wszystkie pomiary były skorelowane (Spearman p<0,001).
Średnia wartość pomiarów głębokości komory przedniej zmierzona przez IOL-Master wynosiła 2,99±0,50 mm, zmierzona za pomocą optycznej koherentnej tomografii przedniego odcinka natomiast wynosiła 2,56±0,46 mm. Różnica była istotna statystycznie (p<0,001). Powyższe wartości były skorelowane (Spearman p<0,001).
Wnioski: wyniki automatycznych pomiarów uzyskanych za pomocą IOL Master mają istotnie wyższe wartości w porównaniu z pomiarami opartymi na bezpośredniej wizualizacji gałki ocznej (optycznej koherentnej tomografii przedniego odcinka i cyfrowych fotografiach).
W celu uzyskania precyzyjnych pomiarów średnicy i głębokości komory przedniej powinno się używać metody pomiaru opartej na bezpośredniej wizualizacji struktur wewnątrzgałkowych.
Słowa kluczowe: „white to white", optyczna koherentna tomografia przedniego odcinka – SL-OCT, IOL Master, fotografie cyfrowe, pomiary.

Introduction

The accurate measurement of the anterior chamber diameter is important for both diagnostic purposes and before some eye surgery procedures. Phakic intraocular lenses have become increasingly popular as an effective and safe treatment of refractive errors. The exact ocular measurements are the key to choosing the appropriate anterior chamber intraocular lens (AC IOL) size and thus avoiding complications. Therefore, for implanting anterior chamber intraocular lenses, including phakic lenses, it is critical to know the internal diameter and the depth of the anterior chamber.

In our previous study (1), we have shown the direct visualization of the anterior chamber (AC) with ultrabiomicroscopy (UBM) to be superior to the white-to-white (WTW) estimation using the photo-based manual measurements in aphakic eyes.

The purpose of this study was to prospectively evaluate the automated measurements of white-to-white distance using the IOL Master with automated measurements of the internal anterior chamber diameter using the slit-lamp adapted optical coherence tomography (SL-OCT) and to compare these values with the WTW distance measured manually using digital photography in healthy phakic eyes, as well as to compare automatic anterior chamber depth (ACD) measurements taken using the IOL Master with manual measurements taken using the SL-OCT.

Material and methods

The analysed data was gathered prospectively from a non-randomized consecutive series of phakic patients. All patients gave their informed consent to participate in the study. All study-related procedures were in line with the Declaration of Helsinki and the study protocol was approved by the Internal Review Board at the Medical University of Lodz (no. RNN/26/14/KE, February 11th, 2014).

The study group consisted of 46 eyes of 39 adult patients, 29 women (74.4%) and 10 men (25.6%) aged from 47 to 87 years old (mean 74.6 years, SD±9).

All patients were phakic and were admitted to the Department of Ophthalmology, Medical University of Lodz for routine cataract surgery. Patients with the history of eye injury, previous ocular surgery or diseases affecting the cornea or sclera were excluded from the study.

We decided to perform all our measurements in the horizontal meridian (3 o'clock and 9 o'clock meridian), as it is typically used for WTW measurements, necessary to choose the appropriate AC IOL size, by ocular surgeons.

WTW diameter was measured using the automated mode of the IOL Master device (Zeiss).

The internal anterior chamber diameter measurements were performed between the two iridocorneal angles, using the Heidelberg slit-lamp-adapted OCT of the anterior segment of the eye (SL-OCT) equipped with standard software which enables accurate measurements on scans using digital calipers (Fig. 1).

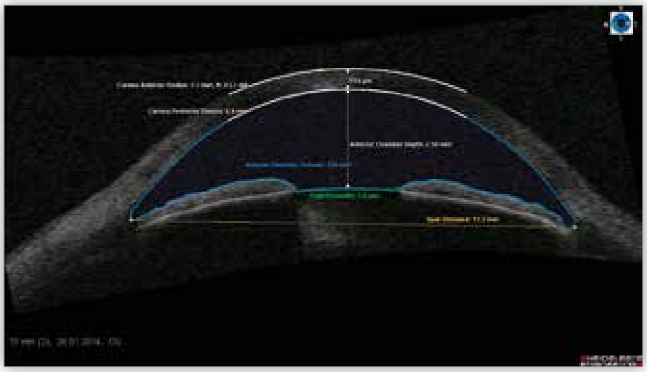

Fig. 1. Internal anterior chamber diameter measurement obtained using SL-OCT.
Ryc. 1. Pomiar średnicy komory przedniej za pomocą SL-OCT.

WTW diameter was also measured on a digital photograph of the anterior segment of the eye, taken using a slit lamp (CSO, Italy) with an in-built digital camera and Epsilon Lyrae software. The photographs were magnified 10-fold, and the software enabled measurements using digital calipers. The image acquisition system provided the resolution of 1280x960 pixels in digital photographs.

The anterior chamber depth was measured using the automated mode of the IOL Master, as well as with the SL-OCT. All measurements were performed by the same examiner (PZA). We also recorded patients' age and sex, as well as potential abnormalities of the anterior and posterior eye segment.

The IOL Master and SL-OCT were calibrated by their respective manufacturers. The digital calipers of Epsilon Lyrae software were calibrated using a photograph of a millimeter ruler.

Statistical analysis was performed using parametric tests. All calculations were done using Microsoft Excel software with Addinsoft XLSTAT 2008 package.

Statistical significance of differences between the unpaired groups was determined using the two-tailed t-test for independent samples. In order to test correlations, Spearman rank-order

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correlation test was used. In order to determine the correlation between the measurements, regression analysis was used. The significance level $\alpha=0.05$ was assumed for all calculations. Differences with $p<0.05$ were considered statistically significant. A Bland-Altman plot (2) was drawn to show the level of conformity between the two methods. A range of conformity (95% limits of conformity) was defined as means ±2 SD of differences between the used techniques.

Results

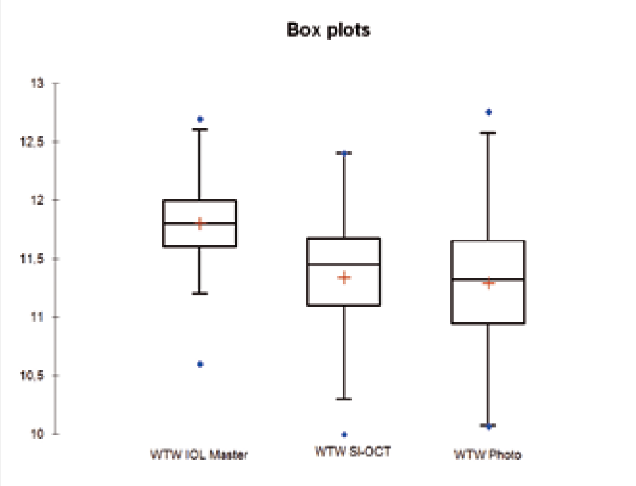
The white-to-white diameter values measured using the IOL Master were compared with the values obtained using the SL-OCT and the slit lamp digital photography.

The mean WTW diameter measured using the IOL Master was 11.8±0.40 mm, whereas the mean internal AC diameter measured using the SL-OCT was 11.34±0.54 mm and the mean WTW diameter measured using digital photographs was 11.29±0.58 mm. The following mean differences between the measurements were shown: the difference between the IOL Master and SL-OCT was 0.46 mm, the difference between the IOL Master and digital photograph was 0.51 mm, whereas the difference between the SL-OCT and digital photograph was 0.05 mm. The detailed descriptive statistics for obtained measurements are shown in Table I and Figure 2.

	WTW IOL Master	AC diameter SL-OCT	WTW Photo
Minimum/ Minimum	10.60	10.00	10.07
Maximum/ Maksimum	12.70	12.40	12.76
Median/ Mediana	11.80	11.45	11.33
Mean/ Średnia	**11.80**	**11.34**	**11.29**
Variance/ Wariancja	0.16	0.28	0.33
Standard deviation/ Odchylenie standardowe	0.40	0.53	0.57

Tab. I. Descriptive statistics for the obtained measurements (mm).
Tab. I. Statystyki opisowe uzyskanych pomiarów (mm).

A significant difference was shown between the mean WTW measurement values obtained using the IOL Master and SL-OCT ($p<0.01$), as well as between the mean WTW measurement values obtained using the IOL Master and digital photograph ($p<0.01$). There was no statistically significant difference between the measurements obtained using the SL-OCT and digital photograph ($p>0.05$). A statistically significant correlation of all values obtained using the discussed methods was confirmed (Spearman $p<0.001$) (Table II).



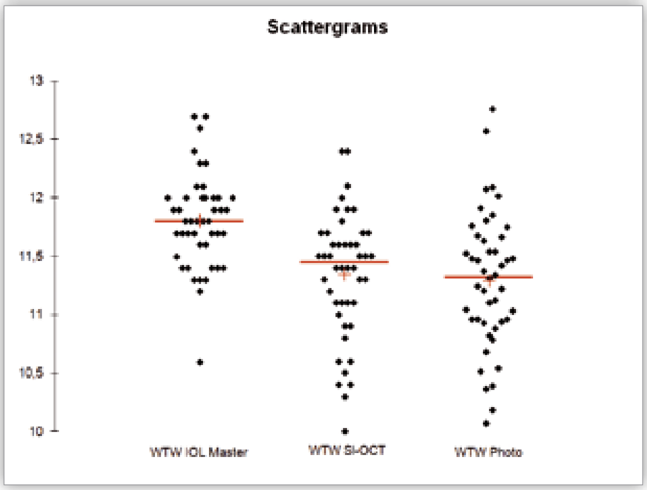


Fig. 2. Box plots and scatter plots for WTW measurements (mm).
Ryc. 2. Wykresy pomiarów WTW (mm).

Figure 3 shows the regression analysis of differences between the measurement techniques used in the study: the regression line being the best-fit line (regression analysis of differences between the horizontal white-to-white distance measured using IOL Master, SL-OCT and digital photography). According to linear regression analysis, the results obtained using the described methods were correlated, but this correlation was not strong (R^2 amounted to 0.362, 0.509 and 0.327, respectively).

	WTW IOL Master		WTW SL-OCT		WTW Photo	
Variables/ Zmienne	Correlation coefficient/ Współczynnik korelacji	p-value	Correlation coefficient/ Współczynnik korelacji	p-value	Correlation coefficient/ Współczynnik korelacji	p-value
WTW IOL Master	1	0	**0.608**	**< 0.0001**	**0.641**	**< 0.0001**
WTW SL-OCT	**0.608**	**< 0.0001**	1	0	**0.597**	**< 0.0001**
WTW Photo	**0.641**	**< 0.0001**	**0.597**	**< 0.0001**	1	0

Tab. II. Spearman correlation coefficients. All values are significantly different from 0 with a statistical significance level alpha=0.05
Tab. II. Współczynniki korelacji Spearmana. Wartości są istotnie różne od zera dla poziomu istotności alfa=0,05.

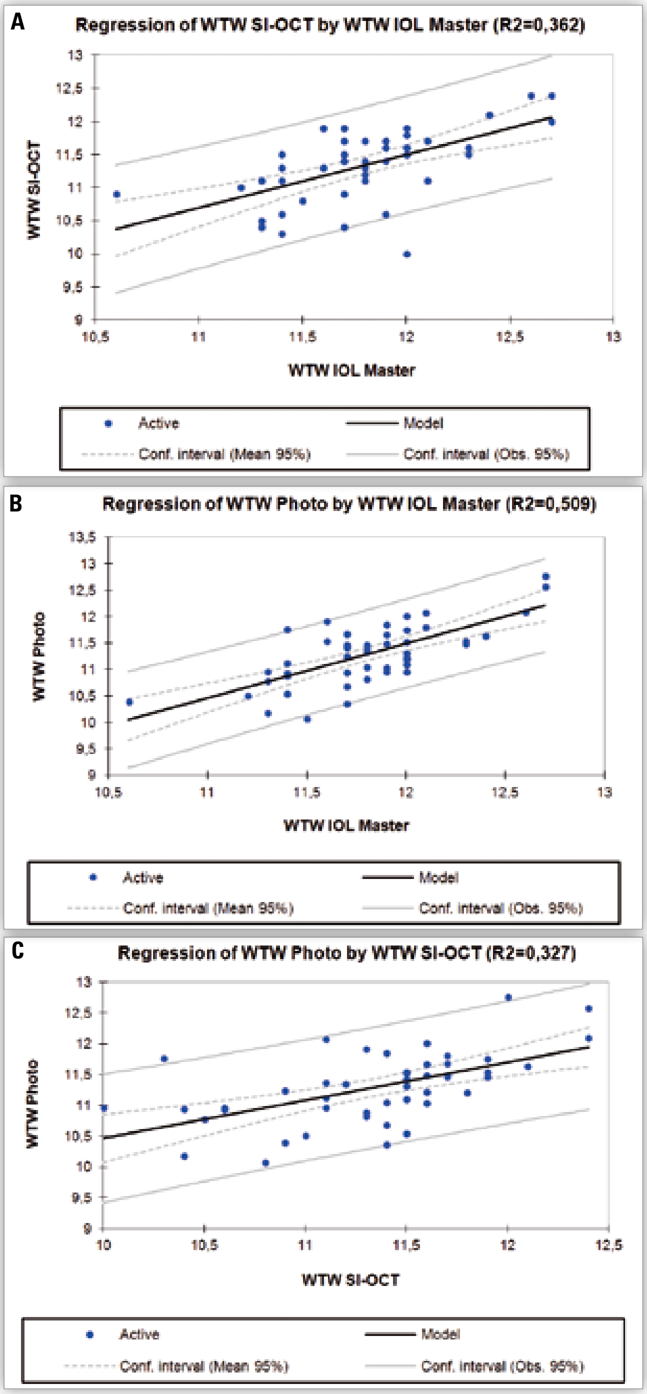


Fig. 3. Regression analysis between the horizontal white-to-white distances measured using IOL Master, SL-OCT and digital photography.
A. Regression analysis for the difference between the measurements obtained using the IOL Master and SL-OCT.
B. Regression analysis for the difference between the measurements obtained using the digital photographs and IOL Master.
C. Regression analysis for the difference between the measurements obtained using the digital photographs and SL-OCT.

Ryc. 3. Analiza regresji zależności między pomiarami średnicy komory przedniej w poziomie wykonanymi za pomocą IOL Master, SL-OCT i fotografii cyfrowej.
A. Analiza regresji zależności między pomiarami wykonanymi za pomocą IOL Master i SL-OCT.
B. Analiza regresji zależności między pomiarami wykonanymi za pomocą fotografii cyfrowych i IOL Master.
C. Analiza regresji zależności między pomiarami wykonanymi za pomocą fotografii cyfrowych i SL-OCT.

The Bland-Altman analysis indicates that all measurements were within the 95% limits of agreement between the two methods (mean difference ±2*SD), however they were not all close to the mean difference line, and some measurements were close to the limit lines (Fig. 4).

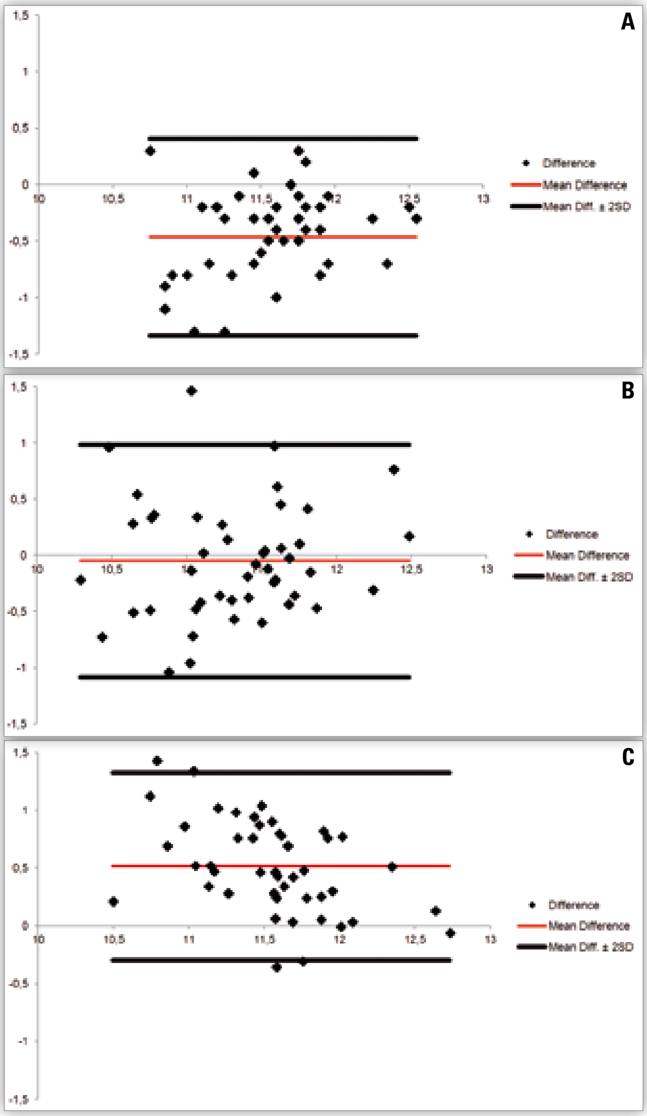


Fig. 4. Bland-Altman plots showing a comparison of two clinical measurements – the conformity between the tested devices. The difference is plotted as a function of the mean for each eye. The horizontal lines represent the mean difference as well as the upper and lower 95% limits of conformity.
A. Comparison of white-to-white measurements obtained using the IOL Master and SL-OCT.
B. Comparison of white-to-white measurements obtained using the SL-OCT and digital photograph.
C. Comparison of white-to-white measurements obtained using the IOL Master and digital photograph.

Ryc. 4. Wykres Blanda-Altmana ukazujący porównanie dwóch pomiarów klinicznych – zgodność miedzy dwoma urządzeniami. Różnica jest ukazana w funkcji średniej. Linie poziome oznaczają średnią różnicę i 95-procentowe granice zgodności.
A. Porównanie pomiarów „white-to-white" uzyskanych za pomocą IOL Master i SL-OCT.
B. Porównanie pomiarów „white-to-white" uzyskanych za pomocą SL-OCT i fotografii cyfrowych.
C. Porównanie pomiarów „white-to-white" uzyskanych za pomocą IOL Master i fotografii cyfrowych.

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Figure 4A represents the conformity of WTW measurements obtained using the IOL Master and SL-OCT, showing the mean difference of 0.46 mm between them, which means these methods do not provide consistent results, and the obtained measurements are not completely interchangeable.

Figure 4B represents the conformity of WTW measurements obtained using the SL-OCT and digital photograph showing the mean difference, which was close to zero and amounted to 0.05 mm. This means that these methods provide consistent results, which are interchangeable.

Figure 4C represents the conformity of WTW measurements obtained using the IOL Master and SL-OCT showing the mean difference of 0.51 mm, which means these methods do not provide consistent results, and the obtained measurements are not completely interchangeable.

The anterior chamber depth measured using the IOL Master was compared with values obtained using the SL-OCT. The mean ACD measured using the IOL Master was 2.99 ±0.50 mm whereas the mean ACD measured using the SL-OCT was 2.56 ±0.46 mm (Fig. 5). The difference was statistically significant ($p<0.001$). Both values were significantly correlated (Spearman correlation coefficient = 0.910, $p<0.001$). The detailed descriptive statistics for the obtained measurements are shown in Table III.

Figure 6 shows regression analysis between the ACD measurements obtained using the IOL Master and SL-OCT. According to linear regression analysis, the results obtained using the described methods showed a strong correlation (R^2 of 0.698).

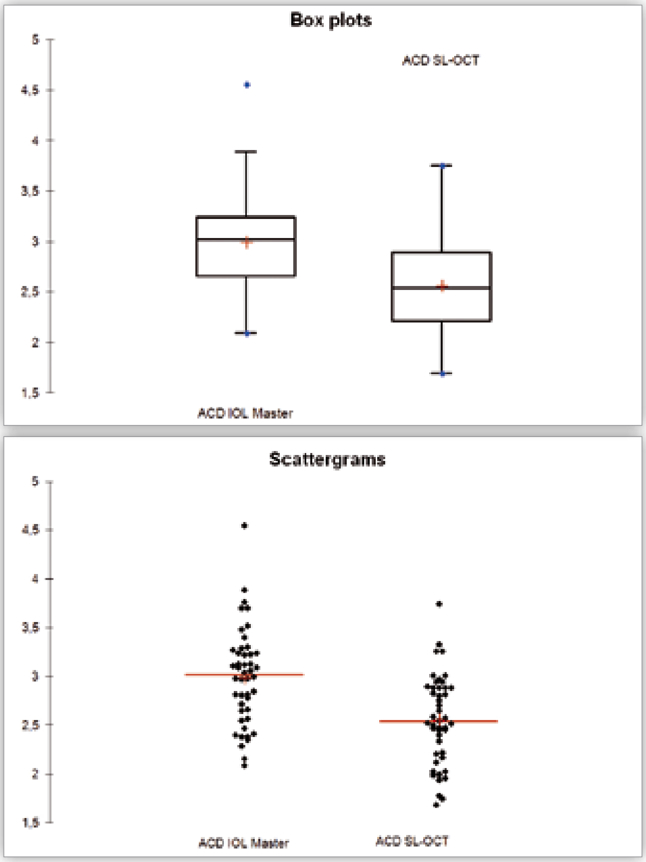

Fig. 5. Box plots and scatter plots for ACD measurements (mm).
Ryc. 5. Wykresy pomiarów głębokości komory przedniej (mm).

	ACD IOL Master	ACD SL-OCT
Minimum/ Minimum	2.09	1.69
Maximum/ Maksimum	4.55	3.75
Median/ Mediana	3.02	2.54
Mean/ Średnia	**2.99**	**2.56**
Variance/ Wariancja	0.24	0.20
Standard deviation/ Odchylenie standardowe	0.49	0.45

Tab. III. Descriptive statistics for the obtained AC depth (ACD) measurements (mm).
Tab. III. Statystyki opisowe pomiarów głębokości komory przedniej (ACD) (mm).

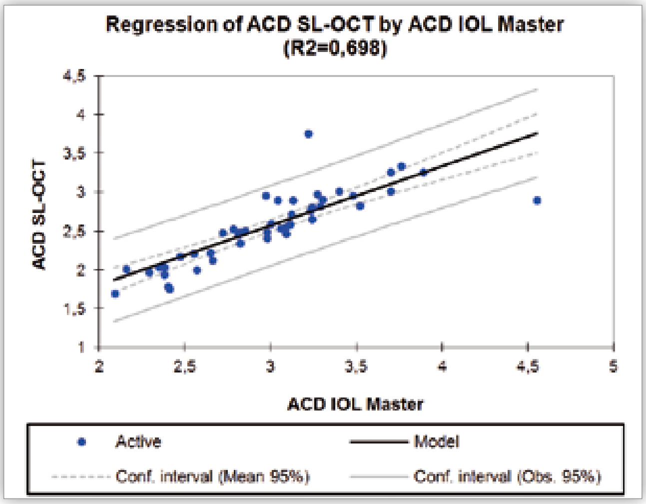

Fig. 6. Regression analysis for the difference between ACD measurements obtained using the IOL Master and SL-OCT.
Ryc. 6. Analiza regresji zależności między pomiarami ACD wykonanymi za pomocą IOL Master i SL-OCT.

The Bland-Altman analysis indicates that the majority of measurements fall within the 95% limits of conformity between the two methods (mean difference ± 2*SD), however they were not all close to the mean difference line, and some measurements were even closer to the limit lines (Fig. 7).

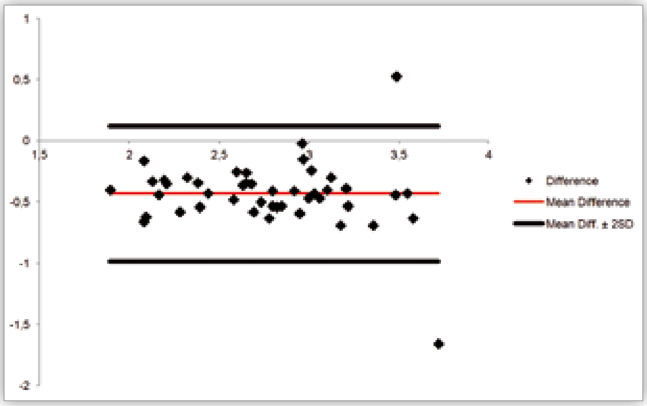

Fig. 7. Bland-Altman plots showing a comparison of two ACD measurements, obtained using the IOL Master and SL-OCT.
Ryc. 7. Wykres Blanda-Altmana ukazujący porównanie dwóch pomiarów ACD uzyskanych za pomocą IOL Master oraz SL-OCT.

Figure 7 represents the conformity of the ACD measured using the IOL Master and SL-OCT, showing the mean difference of 0.43 mm, which means these methods do not provide consistent results, and the obtained measurements are not completely interchangeable.

Discussion

The measurements of the external corneal diameter and the AC diameter are useful for both diagnostic purposes and the preoperative ophthalmic assessment (1, 3, 4).

Currently, the diameter of an AC IOL to be implanted is chosen based on the corneal diameter measurements, also referred to as the white-to-white distance. The accurate measurements (of both WTW and ACD) are particularly important in order to determine the appropriate IOL size before AC IOL implantation and avoid potential complications of improper IOL fitting (3).

Nowadays, secondary IOL implantation is a safe and effective procedure, however, insertion of incorrectly sized IOLs may cause many complications, e.g.: corneal endothelial defects, early transient corneal edema, corneal decompensation (bullous keratopathy), fibrin and inflammatory reaction, uveitis (iritis), angle erosion, decentration and tilt of the IOL, iris capture, pupillary deformation, hyphema, secondary glaucoma, cystoid macular edema and retinal detachment (5–7).

The white-to-white distance and AC depth can be measured using various methods: anterior segment OCT, IOL Master (Carl Zeiss, Meditec), manually with calipers (e.g. Castroviejo surgical caliper), millimeter ruler, UBM, magnetic resonance (MR), AL-Scan (Nidek Co.Ltd.), the Galilei device (Ziemer Group) or Orbscan topographer (Bausch & Lomb) (3, 7, 8). Some authors claim that the automated measurements differ significantly from the results of manual measurements (1, 3, 4).

The IOL Master is a non-contact device used for ocular measurements necessary to calculate the IOL power. The device can provide various measurements, i.e.: axial length of the eye, corneal curvature, WTW as well as anterior chamber depth (4, 5). The IOL Master is one of the first modern devices used for optical biometry. It operates on the principle of partial coherence interferometry, which enables precise and repeatable measurements (4, 5).

Earlier studies compared the measurements obtained using the IOL Master with other techniques. However, most studies analysed the conformity of corneal power or axial length results (9–12). To date, little attention has been paid to WTW measurements taken using the IOL Master. As these measurements can be made using the automated mode only, we decided to compare the results with those obtained using the direct anterior segment visualization (SL-OCT) and manual measurements based on digital photographs of the eye.

SL-OCT is a modern accurate and objective, non-invasive technique of anterior segment visualization. It offers high-quality images, which enable performing precise measurements of various ocular structures.

There are many possible applications of anterior segment OCT in ophthalmic practice. It may be used for measuring corneal thickness, the AC depth, the iridocorneal angles, detecting structural abnormalities of the anterior segment of the eye, objective detailed evaluation of corneal incisions after phacoemulsification and detailed anatomical assessment of the anterior segment (3, 4).

In our group, the internal WTW distance measured using the IOL Master was larger than the AC diameter measured using SL-OCT by approx. 0.46 mm and larger than the WTW distance measured using a digital photograph by approx. 0.51 mm, whereas the mean difference between the WTW measurements done using the SL-OCT and a digital photograph was only 0.05mm. Although values obtained with all these methods were correlated, the results were not interchangeable.

Srivannaboon et al. (13) examined 137 eyes and compared keratometry, axial length, anterior chamber depth and WTW distance, measured using the two optical biometry devices – IOL Master and AL-Scan (Nidek Co., Ltd.). They found that the conformity and correlation between all measurements made using the studied devices were good, except for the WTW. WTW values were significantly (about 0.52 mm) higher when measured with IOL Master, and the correlation between the WTW measured using the two devices was low.

Gao et al. (14) compared WTW distance measured using the IOL Master and UBM in 111 eyes and found a significant difference between the horizontal sulcus diameter measured with UBM and the WTW distance measured using the IOL Master.

Martin et al. (8) evaluated the differences in WTW measurements between Orbscan topography and IOL Master in 328 eyes. They observed significantly higher WTW values obtained using the IOL Master as compared those obtained using Orbscan topography. The authors concluded that the two devices are not clinically interchangeable.

Similarly, Baumeister et al. (4) examined 100 eyes and found that IOL Master yielded constantly higher WTW measurements values as compared to Orbscan.

Kohnen et al. (3) evaluated 52 eyes and found the mean difference of 0.68 mm between the internal AC diameter measured using the anterior segment OCT and the WTW measured using the Orbscan II and a mean difference of 0.36 mm between the internal AC diameter measured using the anterior segment OCT and the measurements done using the IOL Master. They concluded that the direct measurement of the internal horizontal AC diameter using the anterior segment OCT yielded significantly higher results as compared to the automated measurements of the horizontal corneal diameter determined using the IOLMaster or Orbscan. As a result, they pointed to the direct measurement of internal AC diameter as the preferred method.

Nemeth et al. (7) examined 91 eyes and found that WTW distance and internal AC diameter measured using the IOL Master and anterior segment OCT device Visante (Carl Zeiss Meditec) differed significantly, so they were not clinically interchangeable.

Kawamorita et al. (15) examined the WTW distance and ciliary sulcus diameter in 31 eyes using UBM and Orbscan. They found that the conformity between the ciliary sulcus diameter and anterior chamber diameter was high, whereas the conformity between the ciliary sulcus diameter and WTW distance was low. They concluded that IOL sizing based on direct measurement of the ciliary sulcus, as compared to sizing based on the WTW distance, would reduce the risk of improper intraocular lens sizing.

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Pinero et al. (16) measured the WTW distance in 30 eyes using the CSO (Costruzione Strumenti Oftalmici) corneal topography system and the horizontal AC diameter using an anterior segment OCT (Visante, Carl Zeiss Meditec). They found the difference between the two parameters to be statistically significant, the correlation between the measurements to be weak, and concluded that the AC diameter cannot be accurately predicted based on the WTW distance.

In the literature, there are no reports to compare WTW distance measurements done using the IOL Master and anterior segment OCT with direct measurements done using digital photographs of the eye. In our study, the results of measurements based on digital photographs were similar to those obtained using the SL-OCT and significantly lower as compared to the automated measurements obtained using the IOL Master.

The accurate measurement of the AC diameter is essential for choosing a correct size of AC IOL or phakic IOL, especially with angle-supported models.

We believe that SL-OCT is a useful and convenient method for determining the internal AC diameter for secondary AC IOL implantation in phakic eyes. As the IOL Master offers completely automated measurements, the potential for complications due to improper IOL sizing is higher when sizing is based on WTW distance as compared to AC diameter measurements, based on direct anterior segment visualization.

Conclusions

The knowledge of the internal diameter and depth of the anterior chamber is crucial for implanting the anterior chamber intraocular lenses, including phakic lenses.

Automated measurements using the IOL-Master yield constantly higher values than measurements based on direct eye visualization, i.e. SL-OCT and digital photographs.

In order to obtain accurate measurements of the internal anterior chamber diameter and anterior chamber depth, a method involving direct visualization of intraocular structures should be used.

Financial Disclosure

Authors confirm that they do not have any commercial or proprietary interest in any product or company mentioned.

References:

1. Wilczynski M, Bartela J, Synder A, Omulecki W: *Comparison of internal anterior chamber diameter measured with ultrabiomicroscopy with white-to-white distance measured using digital photography in aphakic eyes*. Eur J Ophthalmol. 2010; 20: 76–82.
2. Bland JM, Altman DG: *Statistical methods for assessing agreement between two methods of clinical measurement*. Lancet. 1986; 1: 307–310.
3. Kohnen T, Thomala MC, Cichocki M, Strenger A: *Internal anterior chamber diameter using optical coherence tomography compared with white-to-white distances using automated measurements*. J Cataract Refract Surg. 2006; 32: 1809–1813.
4. Baumeister M, Terzi E, Ekici Y, Kohnen T: *Comparison of manual and automated methods to determine horizontal corneal diameter*. J Cataract Refract Surg. 2004; 30: 374–380.
5. Wong SK, Koch DD, Emery JM: *Secondary intraocular lens implantation*. J Cataract Refract Surg. 1987; 13: 17–20.
6. Lorusso V, Moramarco A, Pacella E, Ballaco-Gabrieli C: *Intraocular lens complications*. Ann Ophthalmol. 1990; 22: 377–381.
7. Nemeth G, Hassan Z, Szalai E, Berta A, Modis L: *Comparative analysis of white-to-white and angle-to-angle distance measurements with partial coherence interferometry and optical coherence tomography*. J Cataract Refract Surg. 2010; 36: 1862–1866.
8. Martin R, Ortiz S, Rio-Cristobal A: *White-to-white corneal diameter differences in moderately and highly myopic eyes: Partial coherence interferometry versus scanning-slit topography*. J Cataract Refract Surg. 2013; 39: 585–589.
9. Santodomingo-Rubido J, Mallen EAH, Gilmartin B, Wolffsohn JS: *A new non-contact optical device for ocular biometry*. Br J Ophthalmol. 2002; 86: 458–462.
10. Sheng H, Bottjer CA, Bullimore MA: *Ocular component measurement using the Zeiss IOLMaster*. Optom Vis Sci. 2004; 81:27–34.
11. Bullimore MA, Buehren T, Bissmann W: *Agreement between a partial coherence interferometer and 2 manual keratometers*, J Cataract Refract Surg. 2013; 39: 1550–1560.
12. Elbaz U, Barkana Y, Gerber Y, Avni I, Zadok D: *Comparison of different techniques of anterior chamber depth and keratometric measurements*. Am J Ophthalmol. 2007; 143: 48–53.
13. Srivannaboon S, Chirapapaisan C, Chonpimai P, Koodkaew S: *Comparison of ocular biometry and intraocular lens power using a new biometer and a standard biometer*. J Cataract Refract Surg. 2014; 40: 709–715.
14. Gao J, Liao RF, Li N: *Ciliary sulcus diameters at different anterior chamber depths in highly myopic eyes*. J Cataract Refract Surg. 2013; 39: 1011–1016.
15. Kawamorita T, Uozato H, Kamiya K, Shimizu K: *Relationship between ciliary sulcus diameter and anterior chamber diameter and corneal diameter*. J Cataract Refract Surg. 2010; 36: 617–624.
16. Pinero DP, Plaza Puche AB, Alio JL: *Corneal diameter measurements by corneal topography and angle-to-angle measurements by optical coherence tomography: Evaluation of equivalence*. J Cataract Refract Surg. 2008; 34: 126–131.

The study was originally received 15.03.2015 (KO-00001-2015-01)/
Praca wpłynęła do Redakcji 15.03.2015 r. (KO-00001-2015-01)
Accepted for publication 15.06.2015/
Zakwalifikowano do druku 15.06.2015 r.

Reprint requests to (Adres do korespondencji):
dr hab. n. med. Michał Wilczyński
Klinika Chorób Oczu Uniwersytetu Medycznego w Łodzi
Szpital Kliniczny Nr.1 im. N. Barlickiego
ul. Kopcińskiego 22, 90-153 Łódź
e-mail: michal.wilczynski@umed.lodz.pl